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Assessment of the sensorimotor integration development in primary school children from Wroclaw, Poland: a prospective observational study

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Abstract

Introduction. Senses are essential in the development of psychomotor functioning in healthy 7-year-old children who enter school. The aim of the study was to assess the level of sensorimotor integration in children starting school education.
Methods. The study involved 82 children from primary schools. The first examination (T1) was carried out at the beginning of the 2018/2019 school year; the second examination (T2) was performed after a 6-month interval. The level of sensorimotor integration development was measured by the Southern California Sensory Integration Test (SCSIT) in 11 sensory categories.
Results. In 10 out of the 11 SCSIT tests, the children obtained statistically significantly higher mean results after 6 months of education (T2) than at the beginning of the school year (T1) ($p < 0.05$). The scores achieved at T1 in SCSIT showed that the following risks of sensorimotor integration disorders were found most often: deep sensation disorders (kinaesthesia test) among 13.4% of the children and incorrect processing of superficial feeling (graphesthesia test) among 12.2%.
Conclusions. The beginning of early childhood education is a difficult period for children to adapt to school requirements. With 7-year-old children starting school education, attention should be paid to their potential difficulties related to abnormalities in deep sensation, especially kinaesthesia (orientation in the positioning of the body parts) and graphesthesia (ability to 'read' shapes).
Key words: children, sensory perception, Southern California Sensory Integration Test (SCSIT)

Introduction

The term 'sensory integration' comes from the Latin words *integratio* (putting the whole together) and *sensus* (sense). The sensory integration process takes place in the nervous system. It is a neurological process that organizes sensations from all the body and the environment; these sensations can be used to generate appropriate responses and deliberate actions. The stimuli from the sensory organs carry a huge amount of information to our brain, which 'processes' the information – locates, recognizes, segregates, interprets – and sends the results to the cerebral cortex, which is the basis for deliberate action in a child. Nerve cells (neurons) located in particular parts of the central nervous system collect and combine information from neurons located in the lower parts of the system. Parietal lobes are among the most important regions of sensory processing. They play a crucial role in integrating sensory information to form a single perception, as well as construct a spatial coordinate system to represent the world around us. Moreover, basal ganglia help initiate and direct voluntary movement. The cerebellum is necessary for the proper coordination of the movement. The higher the levels of the nervous system, the greater the degree of sensory integration. Depending on the needs of the nervous system, selected stimuli are amplified and others are ignored by the reticular formation at the level of the brain stem [1–3].

Learning to perceive and process sensory impressions coming from sense organs begins before the child's birth. Touch is the first evolving human sense. It provides sensory information that enables us to perceive our bodies and sense ourselves in space. During the prenatal development, the foetus perceives movement, touch, hearing, balance, and taste sensations. The amount of sensory stimuli received by a child increases rapidly after birth [4–6].

Sensory integration undergoes significant development in the first year of a child's life [7]. As a child develops, the progress of sensory perception is shaped by the daily activities [4, 5, 8]. Children who experience sensory perception dysfunctions may have problems with 'body sensation' and a reduced ability of motor control, which might translate into the level of physical ability and self-esteem. The basic prerequisite for success in learning is the correct development of the whole body schema, which children should achieve around the age of 6. The lack of developed skills for motor planning and body feeling causes uncertainty and motor clumsiness in children. These dysfunctions are referred to as dyspraxia and result in an impression that the individuals do not understand commands and do not want to execute them properly. Also, motor planning and performing new motor activities are incorrect [9, 10].

Studies conducted in Poland and other countries have indicated a relationship between immature motor and sensory systems and school performance in children [2, 10, 11]. Sensory processing disorders are present in 5–16% of the school-age population of healthy children and 40–80% of children with neurodevelopmental disorders [12].

The study aims to assess the level of sensorimotor integration in children in early education, i.e. to verify whether 7-year-old children respond adequately to the information reaching them through the senses from both the body and the environment.

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Subjects and methods

Participants

For 110 distributed consent forms for participating in the study, 83 parents declared a written consent for their children to participate in the study. One child was excluded from the study owing to a serious visual impairment (Stargardt disease); thus, 82 children were qualified for the study, including 43 (52.44%) girls and 39 boys (47.56%) from 2 primary schools (No. 76 and 113) in Wroclaw. The Participants were 6.61–7.73 years old (mean = 7.23 years, *SD* = 0.31) at the beginning of the school year (T1) and 7.07–8.22 years old (mean = 7.73 years, *SD* = 0.31) after 6 months of education (T2). All children involved in the study were born between 38 and 42 weeks of gestation. Their obtained Apgar score ranged 8–10 in the first minute after birth, which testifies to a good condition of the newborn. The characteristics of the study participants are presented in Table 1.

Table 1. Characteristics of the studied children

Item	Mean	*SD*	Range of variation	
			Min.	Max.
Age at T1 (years)	7.23	0.31	6.61	7.73
Age at T2 (years)	7.73	0.31	7.07	8.22
Week of birth	39.53	1.27	38	42
Apgar score	9.83	0.47	8	10

T1 – the beginning of the school year, T2 – after 6 months

The criteria for excluding children from participation were: lack of written consent from parents/guardians; participation in sensory integration therapy or other specialist therapies in the past or at present; diagnosed neurodevelopmental disorders in infancy; diagnosed neuromuscular diseases; serious vision and/or hearing disability; lack of cooperation during the examination.

Study design

The examination of children took place in a room designated by the school management. Each subject who qualified for the project was examined twice: at the beginning of the school year, in September 2018 (T1); and 6 months later, in March 2019 (T2). Each student was tested individually while at school. One child's examination time equalled approximately 30 minutes.

Research tools

Standardized observation was used as the research method. The Southern California Sensory Integration Test (SCSIT) [13] was applied for technical data collection. SCSIT is a test that assesses the level of sensorimotor integration. It consists of the following 11 tasks: kinaesthesia (KIN); finger identification (FI); graphestesia (GRA); localization of tactile stimuli (LTS); postural imitation (PI); midline crossing (MC); bilateral motor coordination (BMC); left-right discrimination (LRD); standing balance: eyes open (SBEO); standing balance: eyes closed (SBEC); design copy (DC).

For each SCSIT task, the child obtains a certain sum of points (raw score), which is then converted into a standardized score depending on the child's age. The better the child copes with the task, the more points they receive. A score below –0.5 indicates a possible risk of an incorrect level of sensory integration in a given task. A score below –1 indicates a possible risk of sensory integration disorders in a given task.

Statistical analysis

Statistical calculations were performed by using the Statistica version 13.3 program (TIBCO Software Inc.). Quantitative features were described by the following values: mean, standard deviation, minimum, and maximum. Qualitative features were characterized by the distribution of the variables. The distribution of variables was determined by the Kolmogorov-Smirnov test. We used the paired sample *t*-test for variables with a normal distribution to verify the mean differences in the tasks between T1 and T2, and Pearson's chi-squared test to assess the relationship between the 2 nominal variables. The homogeneity of variance in the compared groups was checked with Levene's test. The parametric Student's *t*-test for independent variables served to compare the 2 groups whose data distribution was normal. The results with the significance level of $p < 0.05$ were considered statistically significant.

Ethical approval

The research related to human use has complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the Local Ethics Committee of Wroclaw Medical University, Poland (No. 690/2018).

Informed consent

Informed consent has been obtained from the legal guardians of all individuals included in this study.

Results

In the T1 examination, at the beginning of the school year, in the KIN (proprioception) assessment, 86.59% ($n = 71$) of the examined children obtained a result indicating a correct sensory integration level, and 13.41% ($n = 11$) of children obtained a result indicating possible sensory integration abnormalities. In the T2 examination, in the KIN assessment, as many as 98.78% ($n = 81$) of the studied children obtained a result indicating a normal sensory integration level, and only 1.22% ($n = 1$) of children still presented a result indicating possible sensory integration abnormalities (Figure 1). In the T2 examination, after half a year of implementing the primary school core curriculum, we noted a statistically significantly higher percentage of children with proper functioning of deep sensation (KIN), i.e. perception of the position and movement of the hand in relation to the whole body, as compared with the T1 measurement ($p = 0.0159$) (Figure 1).

The assessment of GRA, i.e. the ability to 'read' shapes, letters, symbols drawn on the pupil's hand without seeing them, showed during T1 that 87.80% ($n = 72$) of children were within the developmental norm, and 12.20% ($n = 10$) presented a possible risk of disorders. The GRA assessment carried out after a 6-month interval (T2) implied that 96.34% of children ($n = 79$) had a good score, and 3.66% ($n = 3$) were at risk of an incorrect level of GRA. In the T2 measurement, after 6 months of participation in school lessons, there was a statistically significantly higher percentage of children with normal GRA functioning than in the T1 measurement ($p = 0.0233$) (Figure 1).

In T1, at the beginning of the school year, in the LRD assessment, 90.24% ($n = 74$) of the examined children obtained

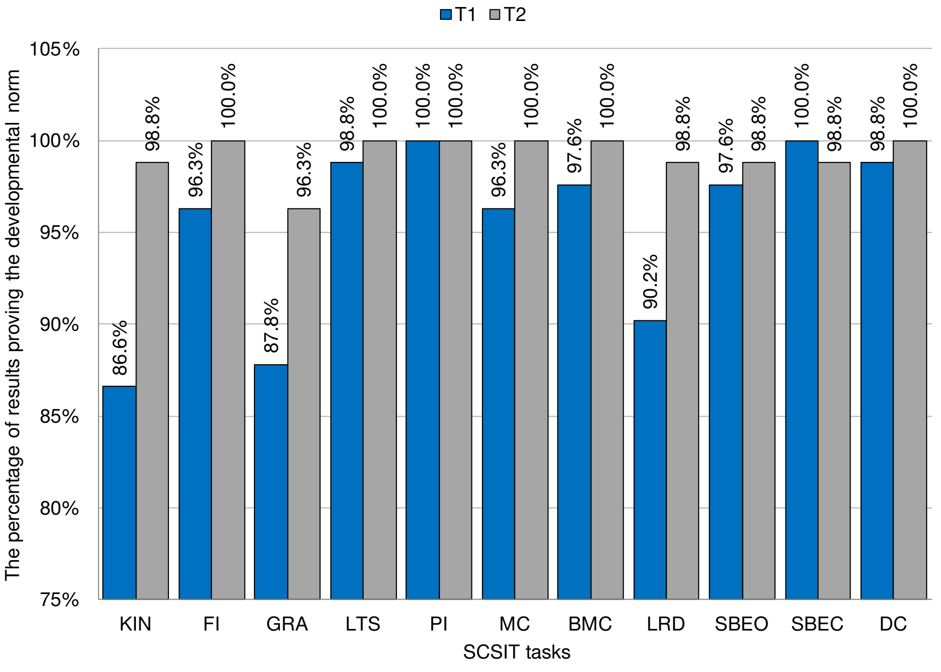

Figure 1. The percentage of results proving the developmental norm obtained in individual SCSIT tasks by the examined children (Pearson's chi-squared test)

T1 – the beginning of the school year
T2 – after 6 months
SCSIT – Southern California Sensory Integration Test
KIN – kinaesthesia,
FI – finger identification
GRA – graphestesia,
LTS – localization of tactile stimuli|
PI – postural imitation
MC – midline crossing
BMC – bilateral motor coordination
LRD – left-right discrimination
SBEO – standing balance: eyes open
SBEC – standing balance: eyes closed
DC – design copy

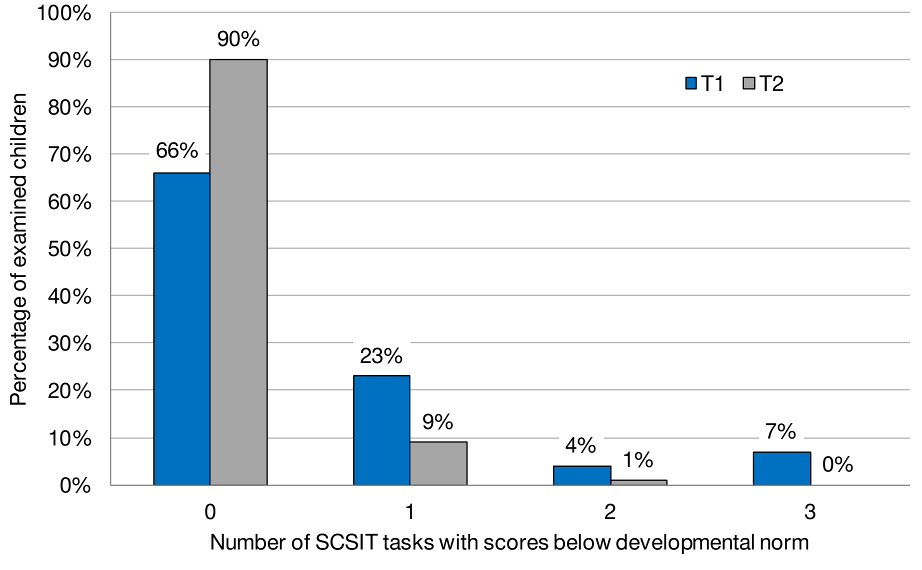

Figure 2. Percentage of examined children who obtained a result below the developmental norm in the particular number of SCSIT tasks (Pearson's chi-squared test)

T1 – the beginning of the school year
T2 – after 6 months
SCSIT – Southern California Sensory Integration Test

a result indicating a normal sensory integration level, and 9.76% ($n = 8$) of children achieved a score suggesting possible LRD dysfunction. In the T2 examination, after 6 months of participation in the school education programme, a statistically significantly higher percentage of children with normal LRD functioning was noted than in the T1 measurement ($p = 0.0412$) (Figure 1). In the T2 examination for LRD, 98.8% ($n = 81$) of children achieved the normal level of sensory integration developmental norm, while an abnormal level was seen in 1.2% ($n = 1$).

In the T1 examination, it was observed that 66% ($n = 54$) of the children had a normal result in all SCSIT tasks; in the T2 examination, as many as 90% ($n = 74$) presented the correct result in all SCSIT tasks.

In T1, results below normal were observed in 23% of children ($n = 19$) in 1 task, in 4% of children ($n = 3$) in 2 tasks, and in 7% of children ($n = 6$) in 3 tasks. In T2, a below-normal result, indicating a possible risk of sensory integration disorder, was found in 9% of children ($n = 7$) in one task, and in 1% of children ($n = 1$) in 2 tasks. None of the examined children obtained abnormal results in 3 or more tasks (Figure 2).

In the T2 examination of the sensory integration level, after 6 months of participation in school activities, a statistically significantly higher percentage of children with a smaller number of abnormal results was recorded than in the T1 measurement of the sensory integration level, at the beginning of the school year ($p = 0.0005$) (Figure 2).

Table 2 presents the results of the sensory integration levels for children in the T1 and T2 examinations. In T2, there was a statistically significantly higher mean than in T1 for the following variables: KIN ($p = 0.0008$), FI ($p < 0.0001$), GRA ($p < 0.0001$), LTS ($p = 0.0001$), PI ($p = 0.0001$), MC ($p = 0.0396$), BMC ($p < 0.0001$), LRD ($p = 0.0028$), SBEO ($p = 0.0212$), DC ($p < 0.0001$). There was no statistically significant difference between the mean scores in T1 and T2 in SBEC ($p = 0.1418$).

Statistically significant differences ($p < 0.05$) were observed in the mean MC (Figure 3), SBEO (Figure 4), and DC (Figure 5) scores in girls and boys in the T1 examination. The mean MC score in T1 was higher in girls than in boys, amounting to 1.02 ± 0.39. In contrast, the mean MC score for boys was 0.64 ± 1.04 (Figure 3). In SBEO, girls scored higher on average than boys. The mean score obtained by the girls was –0.05 ± 0.26 in T1. On the other hand, the mean score achieved by the boys was –0.21 ± 0.35 (Figure 4). The mean T1 DC score in girls was higher than in boys and amounted

Table 2. SCSIT scores in T1 and T2

Item	T1				T2				*t*	*p*
	Mean	*SD*	Range of variation		Mean	*SD*	Range of variation			
			Min.	Max.			Min.	Max.		
KIN	0.44	1.32	–4.55	2.7	1.01	0.98	–2.1	3.0	–3.51	0.0008*
FI	0.59	0.93	–2.0	2.0	1.39	0.53	–0.7	2.0	–9.62	< 0.0001*
GRA	0.54	1.30	–3.2	2.8	1.33	1.02	–1.2	2.6	–7.52	< 0.0001*
LTS	2.08	0.99	–1.6	2.9	2.45	0.68	–0.9	2.9	–3.98	0.0001*
PI	1.58	0.76	–0.7	2.8	2.02	0.56	–0.3	2.5	–7.42	< 0.0001*
MC	0.85	0.77	–3.5	1.2	1.04	0.05	1	1.1	–2.09	0.0396*
BMC	0.70	0.75	–1.3	1.8	1.02	0.48	–0.5	1.6	–6.04	< 0.0001*
LRD	0.53	0.87	–2.4	1.3	0.76	0.71	–2.9	1.1	–3.09	0.0028*
SBEO	–0.12	0.31	–1.2	0.3	–0.26	0.3	–1.4	0.2	2.36	0.0212*
SBEC	1.06	1.10	–1.0	3.3	1.23	1.07	–1.4	3.3	–1.48	0.1418
DC	0.84	0.93	–1.6	2.8	1.37	0.86	–0.2	3.0	–6.22	< 0.0001*

SCSIT – Southern California Sensory Integration Test, T1 – the beginning of the school year, T2 – after 6 months, KIN – kinaesthesia, FI – finger identification, GRA – graphestesia, LTS – localization of tactile stimuli, PI – postural imitation, MC – midline crossing, BMC – bilateral motor coordination, LRD – left-right discrimination, SBEO – standing balance: eyes open, SBEC – standing balance: eyes closed, DC – design copy * statistically significant difference ($p < 0.05$), paired sample *t*-test

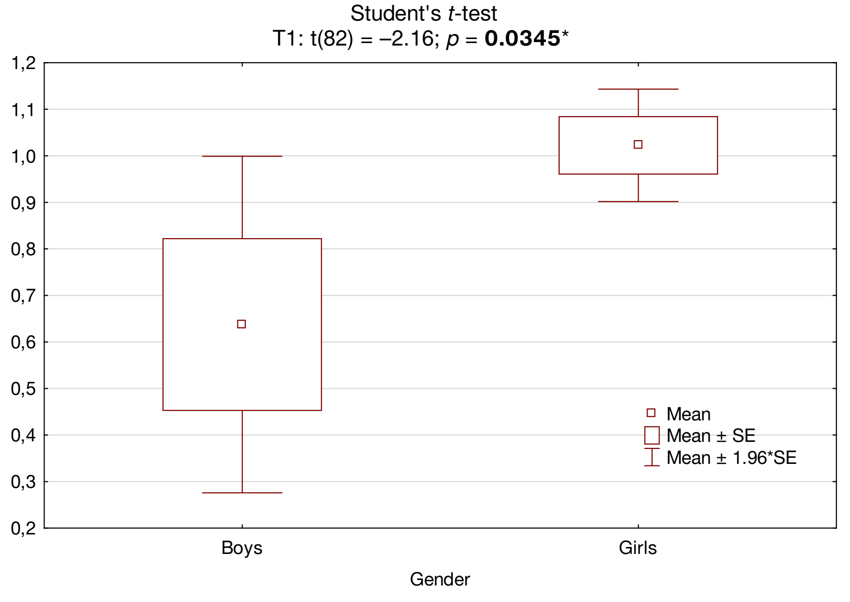

Figure 3. Comparison of mean midline crossing results for boys and girls at the beginning of the school year (T1)

* statistically significant difference ($p < 0.05$)

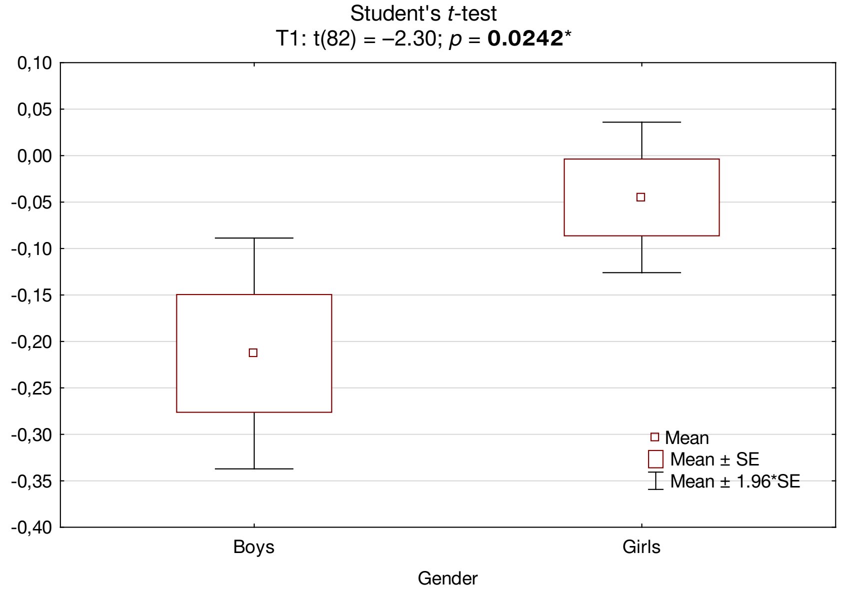

Figure 4. Comparison of mean standing balance: eyes open results for boys and girls at the beginning of the school year (T1)

* statistically significant difference ($p < 0.05$)

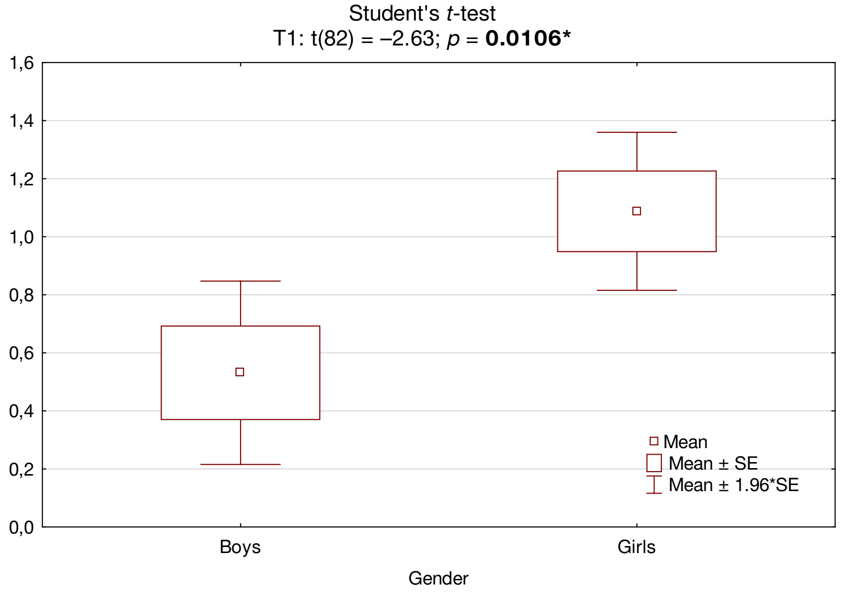

Figure 4. Comparison of mean design copy results for boys and girls at the beginning of the school year (T1)

* statistically significant difference ($p < 0.05$)

to 1.09 ± 0.88. In contrast, the mean DC score for boys was 0.53 ± 0.91 (Figure 5). In the remaining 8 SCSIT tasks, no statistically significant differences were observed between the sexes of the studied children in T1 ($p > 0.05$).

No statistically significant differences between the mean SCSIT results in terms of the gender of the examined children were observed in T2.

Discussion

The present study shows statistically significant differences in the level of sensorimotor perception at the beginning and in the second semester of primary school education in 7-year-old children. The level of sensorimotor perception increased significantly after 6 months of primary school classes. Intergroup statistics revealed a significantly lower level of sensory integration in boys than in girls in the MC, SBEO, and DC tasks at the beginning of the school year. However, after half a year of implementing the core curriculum, the scores levelled off and no significant differences were found between the groups in any of the sensory levels measured.

According to independent studies by Barutchu et al. [14], Dekker et al. [15], and Nardini et al. [16], the optimal level of multisensory perception is formed in children over 10 years of age. The works of other independent authors show that children up to 12 years of age do not fully use visual and vestibular stimuli when controlling their body posture [17, 18]. The research by Brodoehl et al. [19] implies that the threshold of sensory perception is positively correlated with age. The authors' own research shows that the process of sensory perception maturation is intensively shaped in 7-year-old children, starting their education in the first grades of primary schools. There was an increase in the level of perceptual-motor integration measured with SCSIT in 10 of the 11 tasks in first-grade children within 6 months of starting primary school.

Condon and Cremin [20], in a study of 534 children aged 4–15 years from a school in the Republic of Ireland, found that girls had a better sense of balance than boys. De Miguel-Etayo et al. [21], in the IDEFICS study of 10,302 European children, demonstrated that girls performed better in terms of balance than boys. Our reports are similar to the results obtained by these authors [20, 21]. Seven-year-old girls starting primary school education had a better developed sense of balance than their male peers. The boys caught up with the girls in balance after half a year.

Smits-Engelsman and Duysens [22] indicate that the ability of proprioception and kinaesthesia and their integration with other modalities increases with the age of a child. As the child's nervous system matures, the interaction between kinaesthetic-motor and visuomotor internal representations changes. Better use of kinaesthetic-motor information begins to dominate in older children. On the other hand, in younger children, proprioception in a localization task depends to a greater extent on visuomotor maps [22, 23]. For this reason, it was observed in our study that children in the second semester of education had a better ability to 'read' without seeing the shapes drawn on the hand and to feel the position and movement of the hand in relation to the whole body (kinaesthesia test).

Barutchu et al. [14] indicate that the influence of multisensory processing and attention depends on the age and intellectual abilities of children, as well as on the multisensory task and the type of attention necessary for the proper integration of information by the senses. Barela et al. [24] suggest that dyslexic children exhibit poorer performance and greater variability in controlling basic sensory integration processes than their healthy peers. Children with lower cognitive control are also more likely to have lower visual-motor control [25].

Handwriting is one of the necessary motor skills in school-age children. For the correct writing of letters and words, coordination, visual-motor perception, and proprioception are essential. Children with weaker proprioception have problems with the legibility of handwriting owing to too strong or weak pen grip [26]. Ebied et al. [27] indicate that an abnormal superficial feeling may affect the strength of the pen grip when writing on a piece of paper and the qualitative appearance of the handwriting. A study by Falk et al. [28] confirms that the strength of a pen grip strongly correlates with the quality of handwriting. In contrast, poor handwriting legibility is related to the less used area of the brain responsible for spatial memory in children [29]. Proprioception plays an important role in preserving and updating motor memory. Eyesight significance is secondary in handwriting [30].

It seems reasonable to introduce research tools enabling an objective and reliable comparison of the sensory integration levels in children from different countries. Mailloux et al. [31], after examining the patterns of sensory integration dysfunction in 273 children aged 4–9 years, suggested the need to implement objective research tools to analyse the factors of sensory integration disorders, as well as to adapt them to comparative research. In addition, May-Benson et al. [32] recommended establishing a range of sensory integration reference values in the questionnaires used to examine perceptual-motor integration in larger populations of children. It is advisable to use the Evaluation in Ayres Sensory Integration (EASI) test in future research. The EASI test measures sensory integration in a manner that minimizes the impact of language, culture, comprehension, or prior experience. This is a sensory integration evaluation tool with international standards. The EASI test was introduced into research in 2020 (the 100th anniversary of Anna Jean Ayres' birth).

Limitations

This study has some limitations, such as a relatively small sample size and a limited age range (only first-grade students from primary schools).

Conclusions

On the basis of the data analysis, the following conclusions were drawn:

1. The processes of perceptual-motor integration are intensively shaped in children during the first 6 months of their primary school education.

2. Children with a reduced level of development of the body schema and spatial orientation at the beginning of the school year then achieve the developmental norm for their age within 6 months of learning, which proves the development and improvement of senses occurring at that time.

3. At the beginning of the school year, 7-year-old girls are more agile than boys in terms of the development level of body schema (MC), balance (SBEO), and graphomotor skills, such as copying patterns (DC). Boys equalize the development of body schema, balance, and graphomotor skills after 6 months of school education. Boys develop in a different rhythm than girls, which must be remembered in the process of their early school education.

Disclosure statement

No author has any financial interest or received any financial benefit from this research.

Conflict of interest

The authors state no conflict of interest.

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